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Development and Evaluation of a Virtual Terrain Board for Night Vision Goggle Training

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14. ABSTRACT
This report describes the development and evaluation of the Night Readiness, LLC Virtual Terrain Board (VTB) (V2.0c) and its instructional modules for NVG ground training. The evaluation consisted of a training effectiveness assessment of the VTB, using feedback from qualified NVG Training Course terrain board instructors and students undergoing refresher training and students attending initial NVG ground training at six military VTB installations. The primary objectives of the training effectiveness evaluation were to determine if the established terrain board learning objectives could be accomplished with the VTB, to identify additional learning objectives that could be accomplished using the VTB, and to identify areas of improvement required to increase the training value of the VTB system. The results indicated that the VTB is an effective training device that can accomplish most aspects of the established terrain board learning objectives. Specific limitations identified by some instructors and students included demonstrations of the effects of different color/wavelengths of light, illumination levels on halos, and effects related to NVG gain. VTB development currently in progress along with the improvements recommended in this evaluation will provide a balanced, practical approach to improving the usability, versatility and training effectiveness of the VTB.

15. SUBJECT TERMS
NVG, night vision goggles, night vision goggle ground training, terrain board, Virtual Terrain Board (VTB), virtual training

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Executive Summary

Background: The increased use of night vision goggles (NVGs) by the military fixed and rotary-wing communities has created an expanded need for NVG training. The NVG Training Course is the initial curriculum for USAF and USN/USMC NVG aircrew. This training is delivered using platform instruction in a multimedia classroom, hands-on NVG adjustment training in an eye lane, and a scale model terrain board and lighting system to demonstrate various effects to students viewing with NVGs. Advances in virtual environment technologies have enabled the potential for computer-based virtual training systems to accomplish the terrain board learning objectives. The Virtual Terrain Board™ (VTB) takes advantage of advancements in PC-based graphics systems and high-resolution projector capabilities to create a physics-based virtual NVG environment designed to allow the user to accomplish NVG training objectives.

Introduction: This report describes the development and evaluation of the Night Readiness, LLC VTB (V2.0c) and its instructional modules for NVG ground training. The evaluation phase of this effort consisted of a training effectiveness assessment of the VTB, based upon feedback from NVG Training Course instructors and students currently using the VTB at six military installations. The primary objectives of the training effectiveness evaluation were to determine if the established terrain board learning objectives could be accomplished with the VTB, to identify additional learning objectives that could be accomplished using the VTB, and to identify areas of improvement required to increase the training value of the VTB system. The evaluation was designed to elicit feedback from users, both qualified NVG Training Course terrain board instructors and students undergoing refresher training and students attending initial NVG ground training.

Methods: Eleven currently qualified NVG instructors from USN, USAF, and USMC completed both a terrain board learning objectives checklist and instructor survey. Seventy-six VTB students completed a separate VTB student survey. Fifty-one of the NVG students were either USMC or USAF personnel completing their annual NVG refresher training. The remaining 25 participants were students attending either the NVG Instructor Course or the NVG Training Course. All student participants completed a survey immediately following their VTB training session conducted in NVG stimulate mode.

Results: All instructors reported the ability to accomplish the majority of the terrain board learning objectives on the checklist using the VTB. A few instructors indicated that they were unable to fully accomplish specific learning objectives pertaining to the demonstration of the NVG effects of different color/wavelengths of light, moon elevation/angle, halos, and shadows. The overall usability of the VTB was rated as effective by the instructors, although several recommendations were provided to improve the usability of the system. The VTB student survey results were consistent with the instructor results, and indicated that both USMC and USAF refresher students rated the VTB as an effective training system to prepare students for their assigned flying missions.

Conclusions/Recommendations: The instructor and student survey results indicate that the VTB is an effective training device that can accomplish most aspects of the established terrain board learning objectives. There were specific limitations cited by some instructors regarding

the ability to fully demonstrate the learning objectives pertaining to the different color/wavelengths of light, effects of different illumination levels on halos, and effects related to NVG gain. It is recommended that future VTB development efforts address these limitations in the demonstrations related to NVG response to lighting effects, by exploring the use of an auxiliary lighting system or by enhancing the capabilities of the VTB. Additional recommendations aimed at improving system usability included adding the capabilities to generate customized training modules and a more intuitive ability and expanded capability to change lunar phase, elevation, and azimuth to aid in the demonstration of effects related to moon position. The addition of instructional modules to demonstrate environmental and weather effects and threat effects (e.g., ordnance, lasers) is recommended for future VTB efforts. The development plans for the VTB currently underway along with the improvements recommended in this evaluation will provide a balanced, practical approach to improving the usability, versatility and training effectiveness of the VTB.

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PREFACE

This effort was completed by the Air Force Research Laboratory, Human Effectiveness Directorate (AFRL/RHA), Warfighter Readiness Research Division with contractor support from L-3 Communications and The Boeing Company. The work was completed under Contract No. FA8650-05-D-6502, Task Order 0016. The AFRL contractor monitor was Mr. Jay Carroll; the government principal investigator was Capt Joelane E. Lindberg.

This report documents the development and evaluation of the Virtual Terrain Board™ (VTB) (Versions 2.0a-c), developed by Night Readiness, LLC. The VTB system evaluation was carried out in the June-October 2007 time period in collaboration with personnel from Marine Aircraft Group 39 (MAG-39), at Marine Corps Air Station (MCAS) Camp Pendleton.

The information, results, conclusions, and recommendations presented in this document were generated solely from the opinions of the study participants and do not represent USAF policy or endorsement of any product or corporation mentioned.

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Special acknowledgement is due to LT Kimberly Oelschlager (USN), MAG-39, for her assistance in survey development and administration to USMC refresher students at Camp Pendleton. Acknowledgements are also due to the NVG course instructors at the participating USAF, USN and USMC locations who completed surveys and administered surveys to NVG Training Course students. Their efforts in survey administration and diligence in returning completed surveys to AFRL are greatly appreciated.

The authors also acknowledge Capt Christina Price (USAF) who provided valuable support to this effort in partial fulfillment of her Master's degree requirements from Arizona State University.

1. Background

The increased use of night vision goggles (NVGs) by the United States Air Force (USAF), U.S. Navy (USN), and U.S. Marine Corps (USMC) aviation communities has created an expanded need for NVG training (Joralmon, 2004). The Warfighter Readiness Research Division of the Air Force Research Laboratory (AFRL/RHA), Mesa AZ has been developing and distributing such training since the early 1990s (Antonio, Berkley, Fiedler, & Joralmon, 2004; Antonio, Berkley, & Joralmon, 1994, 1998; Joralmon & Antonio, 1992). One product, the NVG Training Course, is the initial curriculum for USN, USMC, and USAF aircrew who fly missions with NVGs. The NVG Training Course is not specific to any one aircraft type as it addresses training objectives common to most tanker, transport, helicopter, fighter, and attack aircraft (Joralmon, 2004).

The Night Imaging and Threat Evaluation Laboratory (NITE Lab) is a standardized configuration for the physical layout of facilities used for NVG training in the US (Joralmon, 2004). A typical NITE Lab consists of a multimedia classroom, an eye lane where NVG adjustment procedures are taught, and a terrain board used to demonstrate various NVG effects. The terrain board is a large (10’ by 10’) model layout of various types of terrain (e.g., desert, mountains, and oceans). Within this varied terrain are different cultural features such as cities, farms, power lines, airports, ships, and bridges. A lighting system over the terrain board enables the instructor to vary the night illumination level between overcast starlight and full moon. A photograph of an instructor using a typical terrain board is shown in Figure 1. The instructor demonstrates to students, who gather around the board and view with NVGs, various NVG effects such as shadowing, cultural lighting, and terrain albedo.

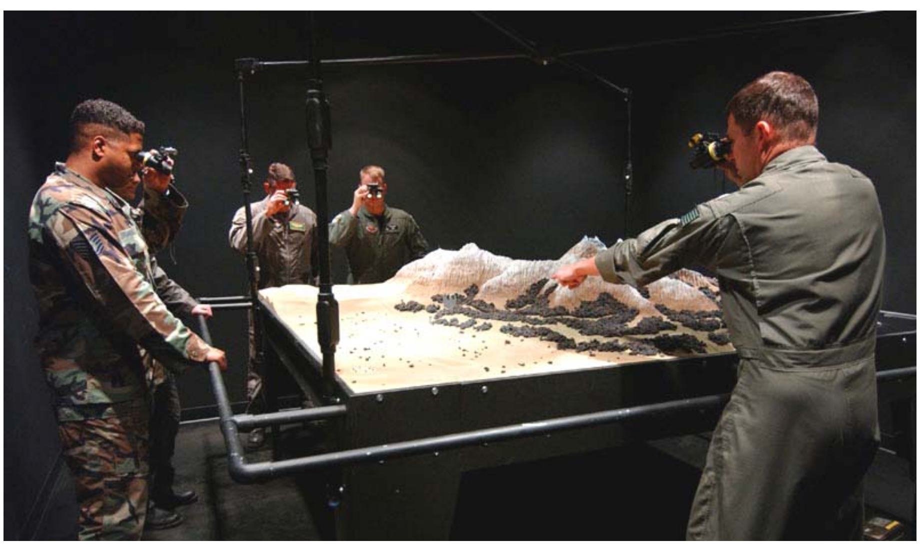

Figure 1. Photograph of a NVG Training Course instructor and students using a terrain board

Advances in visual display technologies and virtual environment interfaces have enabled the potential for computer-based virtual training systems to accomplish NVG training curriculum. The Virtual Terrain Board™ (VTB) developed by Night Readiness, LLC takes advantage of advancements in personal computer (PC)-based graphics systems and high-resolution projector capabilities to create a physics-based virtual rendering of the NVG environment. In the early development stages of the VTB, high-resolution, daytime digital images of real-world locations were combined to create a 360-degree panoramic photo document of the area. These photos were used as a basis for rendering a nighttime scene. Material response data was processed to provide albedo and reflectance for each texel in the scene. Additional features, such as night sky, horizon glow, halos, gain, and noise were combined with the images to create NVG unique effects. Further development of the VTB brought about more location databases (e.g., Whiting Field, Camp Pendleton) created by using the same type of photo manipulation and rendering to illustrate different terrain types, illuminations, contrasts and other NVG affecting variables in various scenes.

The scenes produced by the VTB provide untethered NVG simulation in two modes: simulate and stimulate. The simulate mode displays a NVG scene that can be viewed with the naked eye. The NVG unaided audience may view the scene displayed on the projector screen. In the stimulate mode, the projected image stimulates the NVG to present a real-world NVG-aided scene to the user. The user can also see a rendering of a realistic unaided (out-the-window) nighttime scene when looking under or around the goggles. An initial VTB system was installed in the Night Operations Center of Excellence (NOCOE) research facility at AFRL/RHA in January 2007. This initial version of the VTB leveraged the results of research and engineering development efforts of the AFRL NVG training research team and subcontractor Renaissance Sciences Corporation (RSC) accomplished in the 2004-2005 timeframe. A typical configuration of the VTB in a NVG training classroom environment is depicted in Figure 2. An example of a nighttime NVG-aided scene in the simulate mode of the VTB is provided in Figure 3.

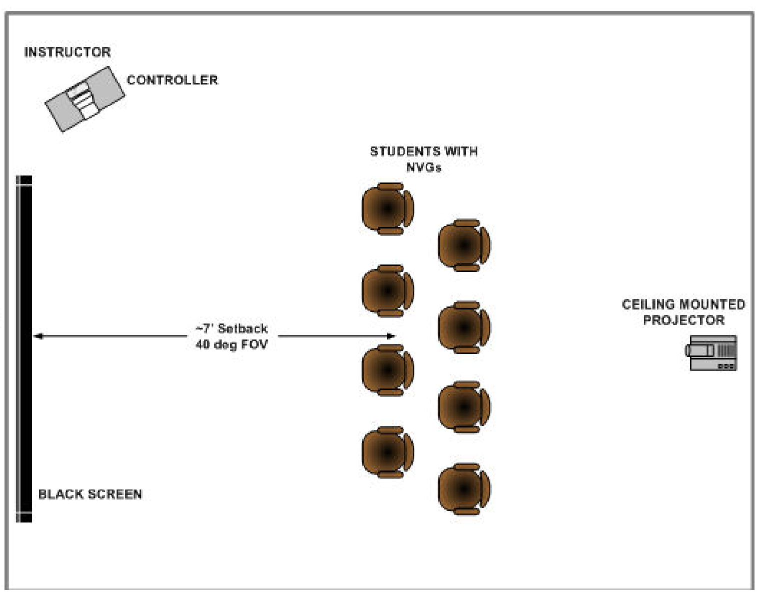

Figure 2. Typical configuration of the VTB system in a NVG training classroom environment

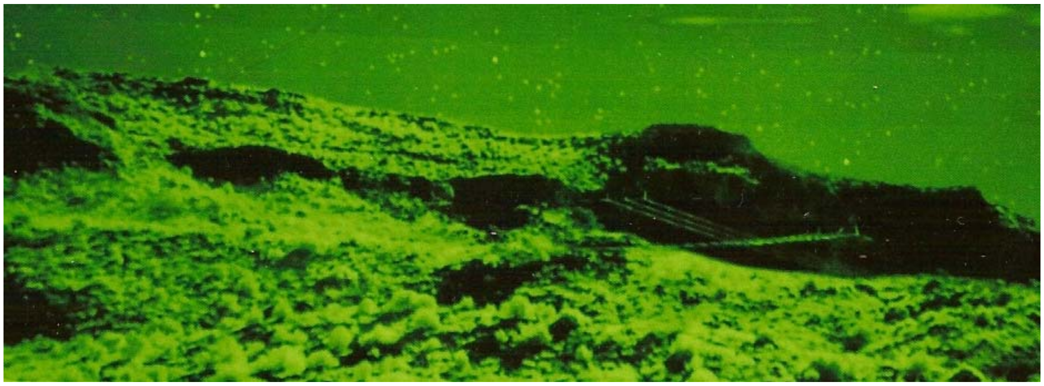

Figure 3. VTB scene of power lines in mountainous terrain in NVG simulation mode (from Night Readiness, 2007)

2. Scope

This report describes the development and evaluation of the VTB (versions 2.0a thru 2.0c) and its instructional modules for NVG ground training. The VTB development efforts encompassed the phases of measurement/calibration of VTB display system settings for NVG stimulation and simulation, development of advanced curriculum modules to accomplish the training objectives of the physical terrain board, delivery of a simulation mode and providing technical support to the collection and delivery of NVG video and digital imagery for use in continued database development and evaluation.

The evaluation phase of this effort consisted of a training effectiveness assessment of the VTB, based upon user feedback from NVG Training Course instructors and students currently using the VTB at six USAF, USN, and USMC installations. The training effectiveness evaluation assessed the effectiveness of the VTB (V2.0c) training modules and instructor guide in accomplishing the terrain board learning objectives established for the NVG Training Course syllabus. These objectives include the demonstration of the effects of illumination and contrast over different terrains, moon elevation and angle, shadows, and cultural/aircraft lighting on NVG operations. Recommendations for future versions of the VTB relevant to design considerations, database features, and instructional modules were also addressed in the evaluation.

3. System Description

The major components of the VTB system are a 3-chip Panasonic digital light processing (DLP) projector, driven by a Dell Dimension 9200 desktop computer. A wireless Dell keyboard and mouse are used for basic computer entry and to access the VTB runtime software. A Logitech Cordless Rumblepad 2 (Model No. C-UE10) gamepad is used for menu control and scene-to-scene navigation. This controller also allows the user to zoom, pan, and turn entities on/off within a scene. A custom filter is fitted over the projector lens to reduce aberrant color contrast effects and optimize the black level of the projector. The projected scene is presented on an opaque black fabric screen (approximately 8 ft wide x 5 ft high) mounted on a wall 12 or 15 ft (depending upon location) in front of the projector. A MenuCube™ software program serves as the interface for instructors to browse through the various database scenes and training modules.

As described in the VTB Instructor Guide (May 2007), the runtime software (V2.0) processes the database for display. Each of the three DLP mirrors in the projector projects a different portion of the spectrum on the screen. One channel displays emissive objects such as cultural lights, moon, and stars. A second channel displays reflective surfaces such as terrain and specific objects, and the third channel displays noise.

The three VTB training modules implemented at the time of this evaluation were entitled Illumination and Contrast, Shadows, and Lighting Effects. Each training module is comprised of several database scenes that are selected to highlight specific training objectives and teaching points. Each scene is presented in a slideshow presentation guided by the instructor. A graphic rendering of the basic VTB system architecture provided by Night Readiness, LLC is displayed in Figure 4.

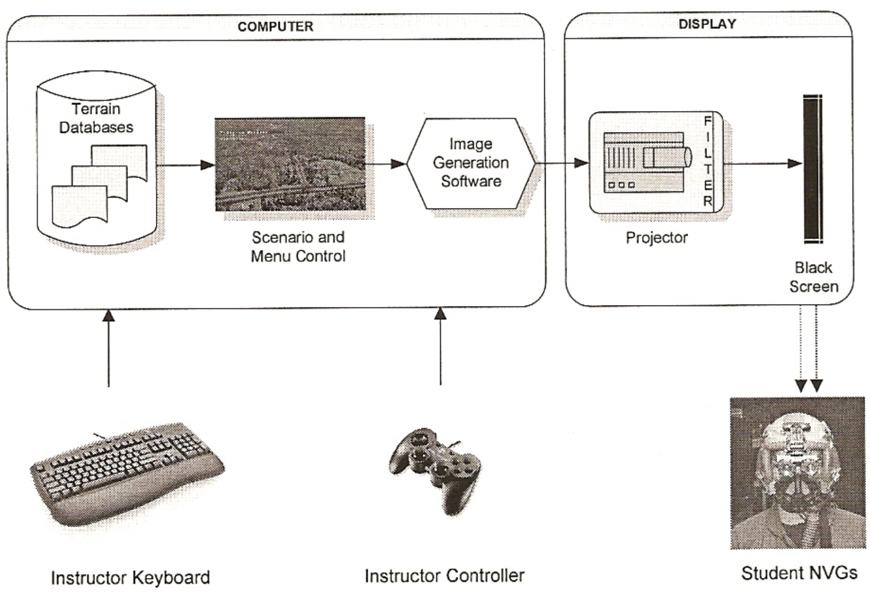

Figure 4. VTB system architecture (from Night Readiness, 2007).

4. VTB Instructional Module Development

The initial version of the VTB training modules software (V2.0a) and supporting instructional materials were delivered to AFRL in April 2007. The training modules delivered with this initial version of the VTB addressed the legacy learning objectives established for the NITE lab physical terrain boards. The modules of illumination and contrast, lighting effects, and shadows contained specific scenes and associated teaching points aimed at each of the terrain board objectives. The illumination and contrast module was designed to demonstrate the effects of various natural illumination levels (from full moon to starlight) over various types of terrain. Specific objectives included the demonstration of illumination level on NVG image quality, differences in albedo for various objects, and the appearance of power lines at different illumination levels. The objective of the lighting effects module was to demonstrate how different light sources affect the quality of the image as well as objects within the scenes. Specific objectives included the demonstration of the effects of different color/wavelengths of light on the NVG image, estimating distances to point light, demonstration of cultural lighting effects on NVGs. The objective of the shadows module is to demonstrate the effects of moon elevation angle and position on shadowing of objects in the NVG image.

A variety of geographical locations were used in the database scene development for each training module. These locations included a series of navigation points along the “Green Route” near Naval Air Station (NAS) Whiting Field, mountainous terrain scenes from Usery Mountain Pass and Four Horse Mesa in Arizona, and scenes derived from satellite imagery from the Mercury, NV region near Nellis AFB. The AFRL NVG research team provided feedback to Night Readiness LLC with respect to content and format of the VTB Instructor Guide as well as desired upgrades to the database of scenes established for each of the training modules described above.

During the quarterly period ending 30 June 2007, Night Readiness upgraded the VTB software to version 2.0c. This version included a simulate mode and updates to the training modules of illumination and contrast, shadows, and lighting effects. The incorporation of the simulate mode allows for a standard classroom or desktop delivery of all existing VTB content. The simulate mode, intended for unaided (non-NVG) viewing, renders all database scenes as they would appear to a user viewing with NVGs. A revised VTB Instructor Guide outlining training objectives and teaching methods for the first VTB instructional modules was delivered during this period.

NVG research team personnel provided additional technical support in defining requirements for a database of NVG scenes tailored to the Marine Corp Air Station (MCAS) Camp Pendleton area to support the specific training needs of that VTB installation. In September 2007, a NVG research team representative participated with Night Readiness LLC in the data collection of high resolution digital imagery using a remote helicopter equipped with photographic equipment. The digital photographs of specific MCAS Camp Pendleton navigation points (i.e., intersections, beach, lake, and 407 Firing Range) were processed to develop nighttime scenes at various illumination levels and added to the VTB scene database.

5. VTB Training Effectiveness Evaluation

5.1 *Introduction*

The terrain board has been an integral part of NVG ground training for the USN, USMC and USAF since its inception. The primary learning objectives of the terrain board instructional module include the demonstration of various NVG effects. The primary terrain board learning objectives are listed below:

- Effects of various illumination levels on contrast/detail over different terrains
- Effects of different color/wavelengths of light under different illumination levels on the NVG image
- Albedos of different objects in high and low contrast areas
- Appearance of power lines
- The effects of different illumination levels on halos
- Effects of shadows on the NVG image
- Effects of moon elevation and angle on the NVG image
- Differences between high and low contrast terrain
- Cultural features such as roads, power lines, runways, and boats
- Effects of cultural lighting

Each objective is addressed using a variety of teaching/demonstration points, depending upon instructor preference and user-specific requirements. In a survey conducted by AFRL to define NVG training requirements for undergraduate pilot training, 516 Instructor Pilots (IPs) with current or previous NVG qualification rank ordered the three learning tools that were most useful to them during their NVG training (Martin, Berkley, Riegler, Good, Anderson, Torruella, et al, 2004). The terrain board was ranked third by the IPs, behind flight training and platform/simulation training. This indicates that NVG-experienced, qualified pilots consider the terrain board a valuable NVG ground training tool.

A major conclusion from the Martin et al, (2004) survey was that realistic NVG simulation has a "unique potential for both highly effective and relatively inexpensive training." These authors recommended that undergraduate pilot training should include NVG simulation exposure. The development and evaluation of the VTB system described in this effort was a significant step in the realization of that goal.

The primary objectives of the training effectiveness evaluation were to determine if the established terrain board learning objectives could be accomplished with the VTB, to identify additional learning objectives that could be accomplished using the VTB, and to identify areas of improvement required to increase the training value of the VTB system. The evaluation was designed to elicit feedback from users, both qualified NVG Training Course terrain board instructors and students undergoing refresher training and students attending initial NVG ground training.

Instructor and student surveys were developed by the AFRL NVG research team to obtain this information from VTB instructors and students at six USMC, USN, and USAF installations. The evaluation was conducted in collaboration with Marine Aircraft Group 39 (MAG-39) at Camp Pendleton, CA who provided feedback from several NVG Refresher Course students who received VTB demonstrations/training during their annual refresher training. These USMC refresher students consisted of rotary-wing pilots (UH-1N, CH-46E, and AH-1W). C-17 aircrew refresher students at Travis Air Force Base (AFB) also participated in the evaluation. NVG Instructor Course students from Randolph AFB and Travis AFB also participated.

5.2 *Method*

5.2.1 Participants

Eleven currently qualified NVG Training Course instructors from USN, USAF, and USMC participated in the evaluation. All instructors had prior teaching experience using the physical terrain board and all had hands-on teaching experience with the VTB (V2.0c) at their NVG training site. Seventy-six VTB students participated in the evaluation at the various USN, USMC, and USAF training sites. Fifty-one of the NVG students were either USMC or USAF personnel completing their annual NVG refresher training. The remaining 25 participants were students attending the NVG Training Course or the NVG Instructor Course.

5.2.2 Surveys

The instructor survey (Appendix A) addressed VTB-user interface issues, ratings of training effectiveness in accomplishing terrain board learning objectives, learning objectives that were not possible to accomplish on the VTB that can be demonstrated on the physical terrain board and vice versa, and recommended improvements to VTB training modules and system capabilities. The terrain board learning objectives checklist (Appendix B) was a one-page checklist of specific terrain board learning objectives designed to elicit a “Yes” or “No” response regarding whether or not the VTB allowed them to accomplish each specific objective. The VTB student survey (Appendix C) addressed the effectiveness of the VTB in familiarizing students with each learning objective, compared the VTB to the physical terrain board in ability to accomplish learning objectives, recommended improvements, and the effectiveness of the VTB in familiarizing a student with their assigned flying mission.

5.2.3 Procedure

The VTB training effectiveness evaluation was officially “kicked off” in June 2007. A request for participation and instructor and student surveys was sent by the AFRL NVG research team to the following NVG Training Course sites:

- Marine Aircraft Group 39, MCAS Camp Pendleton
- Travis AFB Tactics, 60 OSS/OSK, Travis AFB, CA
- Command Training Air Wing Five (CTW-5) NAS Whiting, Field, FL
- 56th Training Squadron (TRS), Luke AFB, AZ
- AETC NVG Instructor Course Schoolhouse (12 ADS/SGGT) Randolph AFB, TX
- AFRL/RHA, Mesa AZ

The support requested from each NVG Training Course instructor POC is outlined below:

- Administration of the instructor survey and terrain board learning objectives checklist to NVG course instructors with terrain board instructional experience with both the virtual and physical terrain boards.
- Administration of the student survey to NVG course students immediately following their demonstration of the VTB.
- Return completed instructor and student surveys

- Availability for follow-up interviews with instructors if necessary

The VTB was demonstrated to students receiving initial and refresher NVG training in the stimulate mode. The demonstrations and surveys were administered by the instructors at the various NVG training sites. Completed surveys were returned via US mail or e-mail to AFRL during the September to December 2007 timeframe.

5.3 *Results*

A summary of the instructor and student survey respondents from each VTB training location is provided in Table 1.

Table 1. Completed instructor and student surveys received from each VTB training location participating in the evaluation

Location	VTB Instructors	VTB Students	
		Refresher	Initial
NAS Whiting Field	5	-	-
MCAS Camp Pendleton	1	31	-
Luke AFB	2	-	-
Travis AFB	1	20	18
AFRL, Mesa	1		
Randolph AFB	1	-	7
Totals	11	51	25

5.3.1 VTB Instructor Survey Results

Eleven instructors from various services including the USAF, USN and USMC completed the VTB instructor survey. These individuals represented the TH-57, C-17, F-16, C-5, AH-1 and CH-46 aircraft communities.

All of the instructors that completed the survey are currently qualified as terrain board instructors. A total of 5 of 11 of those instructors responded that their physical terrain board experience exceeded 100 hours. Six of those surveyed had 8 hours or more of VTB experience.

Terrain Board Learning Objectives Checklist

Ten of the eleven instructors who participated in the evaluation completed a terrain board learning objectives checklist. Instructors used the checklist to indicate “Yes” or “No” as to whether the VTB allowed them to accomplish specific learning objectives. Instructors also provided comments for the learning objectives receiving a “No” response. The results of the terrain board learning objectives checklist are provided in the Table 2.

Table 2. Terrain board learning objectives checklist results

Terrain Board Learning Objectives Indicate whether the VTB allows you to accomplish each specific learning objective.	**No. of Instructors responding YES**	**No. of Instructors responding NO**
1. Demonstrate differences in albedo for different objects	10	0
2. Demonstrate the appearance of power lines	9	0
3. Demonstrate effects of low illumination on contrast/detail over different terrains	10	0
4. Demonstrate the effect of no illumination	8	0
5. Demonstrate effects of different color/wavelengths of light on the NVG image	9	1
6. Demonstrate effects of different color/wavelengths of light under different illumination levels on the NVG image	6	3
7. Demonstrate effects of different illumination levels on halos	7	3
8. Demonstrate effects of moon elevation and angle on the NVG image	7	3
9. Demonstrate differences of albedos in high and low contrast areas	10	0
10. Demonstrate effects of shadows on the NVG image	7	3
11. Demonstrate the effects of various illumination levels on image quality	10	0

As evident in Table 2, all instructors reported that they were able to accomplish the majority of the terrain board learning objectives using the VTB. The terrain board objectives receiving a “No” response by one to three instructors were the VTB's ability to; a) demonstrate effects of different color wavelengths, b) demonstrate effects of different color/wavelengths of light under different illumination levels on the NVG image, c) demonstrate effects of different illumination levels on halos, d) demonstrate effects of moon elevation and angle on the NVG image and e) demonstrate effects of shadows on the NVG image.

Demonstration of the effect of no illumination was not rated by 2 instructors. They did provide comments that a scene presenting the effect of no illumination is not available in the VTB modules. One instructor suggested that this can be demonstrated by powering the NVGs on in a dark, light-tight room.

The comments provided by the instructors who rated low regarding effects of different color wavelengths (objectives 5 & 6) indicated that the effect of the lights needed to be better represented for the unaided view and/or in the NVG image. For objective 5, a suggestion was made that incompatible lights should be shown in a darker shade of red so as to be more easily noticed unaided. One instructor noted that halo size and brightness of non-compatible lights needs to be included in the VTB. Another commented that there was never a difference in halo effects or any changes in the NVG image between the various scenes. One instructor offered the suggestion that on the fly illumination control would alleviate the problem that he noted for objective 6.

The demonstration of the effects of different illumination levels on halos was rated ineffective by 3 instructors. One instructor noted that the halos at different illumination levels were not accurate for the illumination level (e.g. opaque halos at high illumination, not opaque enough at low illumination). The same instructor stated that when zooming in on a light, halo size actually decreases in the demonstration. A third instructor stated that the effect of different illumination levels is not "dramatic" enough but should work better if weather effects are added to the VTB's capabilities.

Three instructors rated the effect of moon elevation and angle demonstration on the NVG image as ineffective. Items that arose for comment from instructors included: goggles do not gain down when directly viewing the moon, and that the capability to change moon elevation while looking at the scene is desired.

Three instructors reported that the VTB did not allow them to fully accomplish the demonstration of shadows on the NVG image. Their comments included the following: there are not enough modules with shadows and effects of objects in shadows, the moon needs to be in field-of-view (FOV) and some shadows do not match with other shadows in scene and capability to change moon while viewing the scene is needed.

Instructors Survey

Usability of VTB:

Instructors rated the ease of use of the overall VTB system using a 5-point scale ranging from very difficult (1) to very easy (5). The instructors gave an average score of 3.8 for the overall ease of use of the VTB system from the instructor's point of view.

The instructors also provided suggested improvements to the VTB regarding its usability with respect to the video controller, menu navigation, classroom environment and the teaching modules provided. Three instructors commented that the video controller would be improved by controller modifications for one handed/hands free control and increased navigation speed. For menu navigation, 8 instructors suggested the ability to edit/customize the modules and menu and 4 instructors noted that an increase in scene to scene transition speed would help. The classroom environment section included instructor's preferences for stadium seating configuration and the ceiling mounted projector for an unobstructed field of view (FOV) for each student. Five instructors commented that the usability of the teaching modules provided could be improved by customization with respect to the order of scenes or the use of site specific databases. Additional teaching modules recommended were addition of medium altitude shot, littoral zone (ocean/sea), weather, threat and time lapse modules by 1 instructor each.

Training Effectiveness Ratings:

Instructors also the rated the training effectiveness of twelve terrain board learning objective using the 5-point rating scale below:

1. Very ineffective – unable to accomplish any learning objectives
2. Ineffective- unable to accomplish most learning objectives
3. Adequate – able to accomplish some learning objectives
4. Effective – able to accomplish most learning objectives
5. Very effective – able to accomplish all learning objectives

Although it is not a defined terrain board learning objective, the effects of environmental factors was included in this section to obtain instructor feedback. Environmental effects are considered additional teaching points and a feature that the military services would like to incorporate into future terrain board modules. Environmental effects are not currently a function of the VTB (V2.0c) or the physical terrain board, although a limited weather simulation was available on some physical terrain boards at various NITE labs. This simulation consisted of a "window" that the NVG user viewed the terrain board through to simulate different weather effects such as fog and clouds. None of these weather windows are currently being used and they are no longer available.

The surveys yielded ratings that averaged 1.5 (between ineffective and very ineffective) for the effects of environmental factors. Many comments regarding the desire for environmental effects as a capability of the VTB were prompted by the inclusion of the feature. The majority of instructors gave very ineffective ratings in this area due to the complete absence of environmental effects from the VTB. Seven instructors noted either the lack of environmental effects or that environmental effects would be a beneficial feature to the VTB. The remaining items in the Table 3 are currently established learning objectives.

The learning objectives rated by the instructors were similar to the objectives cited in Table 2 above, with the addition of cultural lighting and cultural features. The average ratings (of 11 VTB instructors) for each terrain board objective are provided in Table 3. All of the learning objectives listed (excludes environmental effects) had an average rating above 3.5. The majority of them were rated above 4.0, an effective rating.

Table 3. VTB instructors average training effectiveness rating for each terrain board learning objective

Terrain Board Learning Objectives **VTB (V2.0c)** Rate the effectiveness of the VTB in accomplishing the terrain board learning objectives:	**Instructors' Average Rating of Training Effectiveness**
1. Demonstrate both high and low contrast terrain	4.5
2. Demonstrate the appearance of power lines	4.0
3. Demonstrate effects of illumination level on contrast/detail over different terrains	4.4
4. Demonstrate the effect of no illumination	4.1
5. Demonstrate effects of different color/wavelengths of light on the NVG image	4.0
6. Demonstrate effects of different color/wavelengths of light under different illumination levels on the NVG image	3.7
7. Demonstrate effects of different illumination levels on halos	4.1
8. Demonstrate effects of moon elevation and angle on the NVG image	3.8
9. Demonstrate differences of albedos in high and low contrast areas	4.3
10. Demonstrate effects of shadows on the NVG image	4.0
11. Demonstrate the appearance of cultural features	4.5
12. Culturing lighting effects	3.9
13. Demonstrate effects of environmental factors (weather, dust, smoke)	1.5

The instructors rated the extent to which the VTB allowed them to accomplish the overall learning objectives as compared to the physical terrain board. The average rating for the 11 instructors was 4.5.

The instructors were then asked to explain the limitations of those learning objectives marked ineffective or very ineffective. Only one instructor rated any learning objectives (other than environmental factors) as ineffective. This instructor rated both the demonstration of effects of different color/wavelengths of light on the NVG image and this same demonstration at different illumination levels as ineffective.

One instructor elaborated on limitations of those items that he rated as 3, adequate. He rated the following as adequate: demonstrate effects of different color/wavelengths of light on the NVG image, demonstrate effects of different color/wavelengths of light under different illumination levels on an NVG image, demonstrate effects of different illumination levels on halos and demonstrate effects of moon elevation and angle on the NVG image. He addressed these by stating that for the VTB, colored lights are difficult to detect unaided, goggle gain down is not demonstrated well when viewing an incompatible light source, cultural lighting does not illuminate surrounding areas adequately, there are power line visibility issues, halo size decreases when moving towards a light, lights' effects on halos are too opaque or too bright, and overcast starlight is not demonstrated.

Instructors listed any additional NVG training objectives that could be effectively trained using the VTB. Two instructors mentioned mission rehearsal/execution enhancement as another potential learning objective. Additional learning objectives noted by instructors were fly-through capability to improve SA and motion cues, NVG limitations, threat demonstrations, demonstrate aircraft formation lights, environmental factors and motion illusion with moving/stationary light sources.

Instructors were asked to list any learning objectives that are not possible to accomplish on the physical terrain board that can be demonstrated on the VTB. The instructors did not identify any specific learning objectives but instead provided several features/capabilities of the VTB not possible on the physical terrain board. These are listed below:

- Cultural lighting effects on goggle gain
- Zoom and 360 degree scan capability; high fidelity
- Capability for mission preview
- Capability for weather, rain, dust, smoke
- Illusions pertaining to distance estimation to light sources
- Perspective; ability to have a large class see terrain board from the same angle
- Increased number/types of database environments
- Water reflection
- AAA fire/gunfire
- Moving vehicles

Instructors were asked to list any learning objectives that are not possible to accomplish on the VTB that can be demonstrated on the physical terrain board. No specific learning objectives were identified, but the instructors again provided feedback with respect to features/capabilities of the physical terrain board not possible on the VTB:

- Depth perception
- Effects related to moon angle/position
    - Time lapsed moon sequence to demonstrate effect of shadows
    - Better demonstration of different angles of the moon and shadows
    - Ability to easily change moon angle
    - Moon position; corresponding shadows
    - On the fly moon azimuth change and perspective shift
    - Moon azimuth's effect upon visibility of power lines
- Aircraft/ship lighting
- VTB is limited by pre-loaded modules; Physical terrain board has flexibility during presentation
- Mission rehearsal
- Goggle gain effects while viewing incompatible light source
- Halo size change when moving toward object

Six instructors noted that on the fly changes were possible on the terrain board but not the VTB. This included changes in moon angle, azimuth and perspective. Other responses varied greatly as can be seen in the list above.

The instructors then compared the physical terrain board to the VTB with respect to each system's effectiveness as a stand-alone device or if their combined use would provide the most effective training. A total of 11 instructors provided a response for this question. The total statements chosen by all instructors was higher than 11 because the instructor was allowed to select more than one statement for this question.

Seven instructors chose A, the VTB is effective as a stand alone training device. Five instructors chose E, the virtual and physical terrain boards together provide the most effective training. Four instructors chose C, the physical terrain board is effective as a stand alone training device. One instructor chose B, the VTB is not effective as a training device. One instructor chose D, the physical terrain board is not effective as a training device. These results are summarized in Table 4.

Table 4. VTB instructor responses regarding effectiveness as VTB and physical terrain board as stand-alone training devices

Effectiveness of VTB vs. Physical Terrain Board as Training Device	**Instructor Response**										
	1	2	3	4	5	6	7	8	9	10	11
A. The VTB is effective as a stand alone training device		x	x				x	x	x	x	x
B. The VTB is not effective as a training device						x					
C. The physical terrain board is effective as a stand alone training device		x	x				x	x			
D. The physical terrain board is not effective as a training device						x					
E. The virtual and physical terrain boards together provide the most effective training	x		x	x	x	x					

Additional features or capabilities to improve the VTB provided by the instructors are listed below:

- Weather effects – rain/fog/clouds, brownout/whiteout
- Environmental effects – dust/smoke; theater specific environment, aircraft/ship lighting
- Weapons effects - ordnance, lasers, explosions,
- Motion of aircraft – as if actually piloting an aircraft
- Fly through capabilities, real time flight
- Free placement of threat vehicles
- Real time movement of moon angles and intensity
- Ability to physically control/move the moon
- Improve the shadow modules. The database did not generate the effects one would expect to see. Include a scene with various ridge lines and different moon azimuths.
- Landing Signals Officer (LSOs) scenario with sound and ship movement

- Add a threat module to replace Visual Threat Recognition and Avoidance Trainer (VTRAT)
- Provide instructors with a module edit capability.
- Theater specific environment
- Improve halos to be more discernable
- Create a time lapse demonstration
- Speed scene to scene transition/skip through module capability
- Create light sources to affect goggle gain
- Always show halos for incompatible lights
- One hand operation on the controller
- Add runways

The survey was concluded by asking the instructors for any additional comments. Two instructors responded with feedback for this question. One instructor commented that the VTB is a "step in the right direction" and with upgrades to modules and technology, could possibly replace the terrain board. The other instructor noted the VTB's potential of being a stand alone training device, its tailorable databases covering a broad number of environments, ability to provide exposure to actual NVG flight training area, portability/deployability, threat recognition and potential for demonstrating weather effects.

5.3.2 VTB Student Survey Results

The total number of students responding to the survey was 76. A total of 51 participants were NVG refresher training students, 31 rotary-wing USMC aircrew at Camp Pendleton and 20 C-17 aircrew at Travis AFB. The remaining 25 student surveys were completed by USAF personnel attending the NVG Instructor Course or the NVG Training Course. The USMC refresher students had an average of 269 NVG flight hours and the USAF refresher students had an average of 153 NVG flight hours. The refresher student results considered for this analysis included effectiveness ratings for terrain board learning objectives, overall effectiveness as compared to the physical terrain board, potential improvements to the VTB and training points most beneficial in familiarizing students with actual flight operations.

Refresher Students:

All refresher students rated the training effectiveness of each objective as at least adequate (3.0 or higher). The majority of the effectiveness ratings were 4.0 or greater. USMC refresher students rated the effectiveness of each objective lower than the USAF students. The most notable difference in rating occurred with objectives 5 and 6 (related to demonstrations of different color/wavelengths of light) and objective 9 (demonstrate differences of albedos). The average training effectiveness ratings for each terrain board learning objective provided by the NVG Refresher Course USMC and USAF students are listed in Table 5.

Table 5. USMC and USAF NVG refresher course students average training effectiveness rating for each terrain board learning objective

Terrain Board Learning Objectives How effective the VTB was in familiarizing you with the learning objectives listed	**USMC Refresher Students Avg Rating of Training Effectiveness**	**USAF Refresher Students Average Rating of Training Effectiveness**
1. Demonstrate both high and low contrast terrain	4.6	4.8
2. Demonstrate the appearance of power lines	4.1	4.8
3. Demonstrate effects of illumination level on contrast/detail over different terrains	4.3	4.9
4. Demonstrate the effect of no illumination	4.4	4.8
5. Demonstrate effects of different color/wavelengths of light on the NVG image	3.4	4.7
6. Demonstrate effects of different color/wavelengths of light under different illumination levels on the NVG image	3.5	4.5
7. Demonstrate effects of different illumination levels on halos	4.2	4.8
8. Demonstrate effects of moon elevation and angle on the NVG image	4.4	4.6
9. Demonstrate differences of albedos in high and low contrast areas	3.9	4.8
10. Demonstrate effects of shadows on the NVG image	4.5	4.9
11. Demonstrate the appearance of cultural features	4.2	4.8
12. Culturing lighting effects	4.3	4.7

Refresher students also rated the VTB's effectiveness at accomplishing the learning objectives overall in comparison to the physical terrain board. The average rating that USAF refresher students gave was 4.9 and the USMC refresher students average rating was 4.2. The average ratings of effectiveness provided by the USAF NVG Instructor Course and NVG Training Course students were above 4.0 for all learning objectives.

Recommendations for future improvements to the VTB given were given by all students, initial and refresher, USAF and USMC. The percentages for improvements mentioned by all of the students are listed below for the top three mentioned items. All others were mentioned by 5% of the students or less. They included the following:

- Fly through capability (18%)
- Threats: ordnance, lasers, explosions, VTRAT integration (13%)
- Theater specific environment/tactical visual features (8%)
- Weather/environmental effects (8%)
- Smoother movement with controller/allow for slower movement
- Local areas/routes
- Different altitude scenes

- Edit/customization of modules/menu
- Diversify terrain
- Add cultural features
- Depth Perception

Refresher students were asked to rate the effectiveness of the VTB in familiarizing students with assigned flying missions. The average rating that USAF refresher students gave was 4.7 and the USMC refresher students average rating was 4.0. Refresher students also identified the VTB training points that are most beneficial in familiarizing students with actual flight operations. The percentages of comments received for a particular training area are listed for the top three mentioned items. All others were mentioned by 5% of refresher students or less.

- Different moon illuminations/positions (31%)
- Terrain and contrast levels (18%)
- Shadowing effects (8%)
- Airfield/runway environments
- Cultural vs. aircraft lighting
- Weather
- Ordinance
- Over water
- Physical features

6. Conclusions

The results of the terrain board learning objectives checklist and the instructor survey indicate that most instructors can accomplish all terrain board learning objectives using the VTB. However, a few instructors identified specific learning objectives that they were unable to fully accomplish. The learning objectives noted as not being able to fully accomplish using the VTB by three instructors were: demonstrate effects of different color light under different illumination levels on an NVG image, demonstrate effects of different illumination levels on halos, demonstrate effects of moon elevation and angle on the NVG image and demonstrate the effects of shadows on the NVG image. Two instructors did not respond with "Yes or No" but instead with comments on demonstrate the effects of no illumination objective. Although most instructors indicated that the VTB does accomplish each learning objective, the presence of some instructors choosing "No" or not responding "Yes or No" but including comments indicates that there are some improvements that should be made or additional training devices that should used to support the VTB for teaching these learning objectives.

In its current configuration, external light sources (including the moon) and associated halos contained in VTB scenes are simulated and do not stimulate the NVGs as accurately as actual real-world emissive light sources. The physical terrain board is equipped with incandescent light sources that vary in color and intensity, and are used to stimulate the NVGs to produce the desired effects. The physical terrain board lighting system used for the moon simulation also drives the gain response of the NVG, when lights are in the field of view of the NVG. The results of the learning objectives checklist with respect to demonstrations of different color lights and halos indicate that improvements to the VTB to allow for better demonstration of lighting effects and halos are warranted. The differences between the VTB and physical terrain board lighting systems may also contribute to the limitations in the effects of moon angle and shadow demonstrations noted by three instructors.

The overall ease of use of the VTB was rated by instructors as above satisfactory and nearly somewhat easy with an average rating of 3.8. The instructors were questioned about the usability of the VTB pertaining to the video controller, menu navigation, the classroom environment and the teaching modules provided. Over half of the instructors commented that the ability to edit/customize the modules and menu would improve the usability of the VTB. This data suggests that one improvement to enhance the usability of the VTB in more than one area is to develop the ability to customize the training modules based on the needs of the instructor. Four instructors also noted that a quicker scene-to-scene transition time would improve the usability of the VTB. Also, some instructors mentioned that a one-handed control would improve usability. One instructor noted difficulty holding NVGs due to use of Clip-On Power Source (CLOPs) and manipulating the VTB simultaneously. These comments suggest that the instructors were holding the NVGs in one-hand and the video controller gamepad in the other. One solution might be to wear the NVGs on a helmet to free up both hands for using the gamepad. Another solution might be the implementation of a controller that can be more easily operated with one hand (i.e., a remote control device).

All instructors rated the training effectiveness of the 12 terrain board learning objectives at 3.8 or above using the 5-point scale, indicating that the instructors found the VTB to be an effective tool for demonstrating most aspects of the terrain board learning objectives.

One USN/USMC instructor rated at a level of ineffective the demonstration of the effects of different color/wavelengths of light on the image and under different illumination levels on the image. The instructor identified the reason for these ratings as a need for improved color/wavelength for aided and unaided for the VTB. The average rating given for these two objectives were 4.0 (on NVG image) and 3.7 (on NVG image at different illumination levels), indicating that the majority of the instructors could accomplish most of the teaching points associated with the two objectives. These results are consistent with the terrain board objectives checklist findings discussed previously.

The USMC refresher students also rated objectives related to the demonstration of different colors/wavelengths of light notably lower than the USAF students. The instructors that commented on this learning objective were all USMC instructors. This indicates that the learning objective related to the demonstration of colors/wavelengths of light may be a more crucial learning objective to the USMC.

The USMC refresher students also rated consistently lower in for effectiveness of all objectives and over all effectiveness when compared to the physical terrain board. The different flight missions of the USMC and USAF and the finding that USMC refresher students, on average, had nearly twice as many NVG flight hours may contribute to this difference. The USMC refresher students may be more discerning observers given the nature of the flight missions they are assigned (low-level). Also, many effectiveness ratings for the USMC students were marked as "not-applicable" indicating that they may have had little or no exposure to the particular objective indicated on the survey.

Other potential demonstrations identified by the instructors for effective VTB training included environmental effects. Environmental effects are not a current capability of the VTB and were rated very low on the learning objective scales because they are not a feature of the version of the VTB (V2.0c) evaluated for this effort. Over half of the respondents listed environmental effects as an effectively trainable learning objective. Also, environmental/weather effects were commented on repeatedly in the survey by the instructors. This is an indication that the inclusion of environmental/weather effects will be an important feature to include during further development of the VTB.

The instructor feedback regarding learning objectives that were not possible to accomplish using the physical terrain board that can be demonstrated on the VTB showed various responses. The only response that was given by two different instructors was the weather, dust and smoke effects as a learning objective. As stated previously, this answer arose in several different questions. Other objectives listed included weapons employment, mission planning and rehearsal and demonstration of various threats.

The instructor feedback regarding learning objectives not possible to accomplish on the VTB that can be demonstrated on the physical terrain board also varied greatly. One objective that was mentioned consistently was effects related to moon angle/position. Six of the eleven instructors noted that the demonstration of the effects of moon elevation angle and position could be more readily demonstrated on the physical terrain board. This shows that this is an important capability used whose absence is noticed among VTB users. Other capabilities of the physical terrain board that were noted as being not capable on the VTB included aircraft/ship lighting effects, limitation of pre-loaded modules; and goggle gain effects while viewing incompatible light source.

Instructors were asked to mark each statement that applied in a comparison between the physical terrain board and the VTB. Two statements each were given for the independent use of the two systems: (A) the VTB is effective as a stand alone training device or (C) the physical terrain board is effective as a stand alone training device. Two stated the opposite: (B) the VTB is not effective as a stand-alone training device and (D) the physical terrain board is not effective as a stand-alone training device. One more statement was added indicating that (E) the virtual and physical terrain boards together provide the most effective training.

The results indicate that 7 instructors surveyed believe that the VTB is effective as a stand alone training device. Five instructors indicate that the most effective training method is using these two devices together. The selection of either A or E by all of the instructors indicates that they consider the VTB, as either one element for training with the physical terrain board or by its sole use as a trainer, beneficial to the trainee for effectively conveying the terrain board learning objectives.

VTB instructors identified improvements that they would recommend for the VTB. The list given by the instructors varied greatly showing that there is still room for improvement for the

VTB. Again, environmental/weather effects and real time movement of moon angles and intensity was noted in this section.

Additional comments were requested at the completion of the survey. Two instructors responded to this section. Both comments given indicated that these individuals see the VTB as a progression in technology. At the same time, these instructors indicate that although is a step forward, there are still ways that it can be improved.

Overall the survey results indicated that the majority of the instructors surveyed believe that the VTB adequately and effectively trains for the current terrain board learning objectives. Most of ratings given by instructors for effectiveness ranged between 3, adequate and 5, very effective. As the individual objectives are examined, however, improvements still can be made in different learning areas to make VTB more effective.

The most prominently mentioned capabilities for VTB development are environmental/weather effects and the ability to change moon angle and position. The addition of these capabilities could potentially eliminate several of the items listed as limitations of the VTB. Regarding the usability of the VTB, the ability to modify and edit the training modules was mentioned frequently.

Overall, the instructors rated the VTB favorably as part of their training programs as either a stand alone training device or when used in conjunction with the physical terrain board. In the future, the suggestions given for additional learning objectives can be used to develop the VTB further for relevant training in other areas in addition than those currently trained with the terrain board.

Both NVG Refresher and NVG Instructor Course students listed areas of improvement for the VTB. Many echoed the responses of the instructors with respect to including fly-through capability, threats, weather/environmental effects, different altitude scenes, and edit/customization of modules/menu. The instructors rated lower than all of the refresher students in only two areas: effects of moon elevation and angle on the NVG image and cultural lighting effects. One item mentioned frequently by USAF students was the potential use of the VTB as a platform for the VTRAT.

Across all ratings; the effectiveness of VTB at accomplishing specific learning objectives, at familiarizing students with assigned flying missions and overall effectiveness, the USMC students rated slightly lower than the USAF students. Possible explanations for this are that the USMC refresher students have more NVG flight hours on average than the USAF refresher students (269:153) and were more sensitive to the limitations of the VTB and perhaps more discerning in their evaluation of learning objectives. Also, the USMC and USAF refresher students' flying missions are different, and thus would likely offer different perspectives. USMC students consisted of rotary-wing aircrew, whereas USAF students were fixed-wing pilots.

Refresher students commented on VTB training points that are most beneficial in familiarizing students with actual flight operations. Their responses reflected current and potential training points that could be shown on the VTB. The USMC students mentioned weather, ordnance, over water flight, and shadowing. The USAF students noted halo effects, cultural vs. aircraft lighting and shadowing. As listed previously, all refresher students noted varying illumination, terrain/contrast and fly through capability.

Nonetheless, these results suggest that different flying communities will have different training requirements with respect to VTB learning objectives. This lends further support to the concept of providing a better capability to customize/edit training modules to accommodate these differences in requirements.

7. Recommendations

Based on the instructor and student feedback obtained for this evaluation, the VTB does effectively accomplish most aspects of the established terrain board learning objectives. However, further development is recommended in order to increase the VTB's training effectiveness for specific objectives and to more fully realize its training value.

It is recommended that future development efforts of the VTB be aimed at improving system usability and the realism of NVG effects in the specific areas outlined below. These recommendations are based upon the comments/ratings obtained from both qualified NVG instructors and NVG-experienced aircrew and are designed to enhance the training value of the VTB. The following list provides areas in which development efforts should be focused in future updates to the VTB.

<u>Weather and environmental effects.</u> Recommend effects such as snow, rain, fog, dust, smoke, etc. be added to future training modules of the VTB. Provided that the VTB technology has the capability, the majority of instructors noted that the addition of weather and environmental effects would relieve some of the limitations of the VTB in its current state.

<u>Add threat module(s)</u>. Recommend adding threat modules to simulate threat effects to include ordnance, lasers, and explosions. The addition of a threat module would expose students to NVG effects caused by threats and could possibly replace or be integrated with VTRAT.

<u>Lunar azimuth and elevation control</u>. A more intuitive ability and expanded capability to change lunar phase, elevation, and azimuth. Adding this capability may address the some limitations encountered in the VTB shadow module.

Within the existing configuration, this recommended improvement could be accomplished by displaying scenes in a logical, timed sequence which gives the effect of moon position changes. This could be done by using the current configuration and runtime software to develop additional instructor modules that illustrate the effects of moon elevation, azimuth and phase. For example, a module with stepped changes in elevation over several different scenes can be created to demonstrate the impact that these changes have upon the scene. The instructor could emphasize the changing shadows and other effects as they relate to elevation changes.

An alternate and preferred method to control the moon phase, elevation and azimuth is to develop an on-the-fly ability to manipulate the moon position as desired by the instructor. Moon control will affect the shadows and illumination displayed in the scenes and can be changed in real time at the discretion of the instructor. In this case, the control parameters would be similar to those demonstrated on the physical terrain board.

Customization of modules. VTB software should allow the instructor to develop custom modules tailored to each unit's training needs. For example, instead of having to show an entire module as it is sequenced by the software designer, the instructor would be able to select the scenes that they wish to use for their class by designing a custom module to demonstrate to their students.

Expansion and improvement of the shadow module. Create an expanded selection of scenes in shadow module and improve upon the existing scenes. The database should be improved to generate shadows and objects in shadows as they are expected to be seen. The shadows module should also be expanded to include more complex scenes. For example, a scene with shadows created by various ridge lines and/or objects in the shadows.

Improve halos. The halo representations should be improved to provide an accurate representation of how halos look through NVGs. One issue is that halo size decreases or remains constant when zooming in towards a light in the demonstration. Also, in certain scenes halos from lights are either too opaque or too bright.

Improve different color/wavelength of light depiction. Improvements to color light depiction for unaided view are recommended. Colored lights within the VTB scene are difficult to detect unaided. A light bar can be used as an auxiliary training device for demonstrations of colored lights and how they look aided and unaided. The use of a light bar may provide a better a physics-based demonstration of how NVGs react to multi-colored and/or incompatible lighting.

Improve goggle gain effects: Creating incompatible lights that can affect goggle gain in the NVG is recommended. Incompatible lights, such as the moon , do not gain down the goggle accurately. The incorporation of the light bar mentioned above might also serve to demonstrate NVG gain effects.

Zero illumination scene(s). Currently, none of the modules available depict a scene with no illumination. As part of the instruction, it is recommend turning out all room lights in a light-tight dark room to demonstrate that at least some light is needed for the NVG to amplify and provide the user a perceptible NVG image.

Improve controller. Recommend exploration of alternative control options to replace the existing video controller in order to allow one-handed control of the VTB.

The strong presence of each of these items in the comments sections of the survey indicates that there is a need for improvement and/or additional capabilities in these areas. By further development in the recommended areas, the VTB's potential for more effective training of current and new terrain board learning objectives should be increased.

8. Summary

Night Readiness, the VTB manufacturer, plans to expand several capabilities of the VTB in the near future. The version evaluated here was 2.0c. Current plans for future VTB development include weather/environmental effects, improved database generation using commercially available software, advanced real-world scenes documentation and fly through capabilities using government-off-the-shelf (GOTS) software. The addition of these capabilities will allow for:

- Mission pre-brief and preview
- Post-mission critique
- Mishap Investigation
- Geospecific databases
- Rapid development of 1000 square mile databases
- Demonstration of weather/environmental effects

Future development in the areas listed will address most of the improvements desired by the instructors and students surveyed. The results of the evaluation conducted show that the VTB effectively accomplishes most of the learning objectives of the terrain board and with the implementation of auxiliary devices (e.g., light bar) and improvements to database scene realism, may accomplish all of them effectively. The development plans for the VTB currently underway along with the improvements recommended in this evaluation will provide the most balanced approach to improving the usability, versatility and training effectiveness of the VTB.

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10. Acronyms

AFB	Air Force Base
CDRL	Contract Data Requirements List
COTS	commercial off-the-shelf
DCS	DMO Control Station
DVT	Desktop Visualization Trainer
HMD	Helmet Mounted Display
HUD	Heads-Up Display
I/ITSEC	Interservice/Industry Training, Simulation & Education Conference
IG	Image Generator
LANTIRN	Low-Altitude Navigation and Targeting Infrared for Night
MRS	Mesa Research Site
NVG	Night Vision Goggle
NVTS	Night Vision Training System
OTW	Out-the Window
PETS	Performance Evaluation and Tracking System
PFPS	Portable Flight Planning Software
PI	Principal Investigator
PNVG	Panoramic Night Vision Goggle
RCG	Rickard Consulting Group
RSC	Renaissance Sciences Corporation
SBIR	Small Business Innovative Research
SME	Subject Matter Expert
SOW	Statement of Work
SPINS	Special Instructions
SSOW	Subcontractor Statement of Work
TMWP	Technical Management Work Plan
UWB	Ultra Wide Band
ViPRS	Video Processor for Real-time Simulation
VTB	Virtual Terrain Board

11. Appendix A: VTB Instructor Survey

Virtual Terrain Board Survey
Instructors

Name: ______________________ Courses Administered:_____________________
Rank: _______________________ Aircraft:____________________________
Service: ____________________ Date:_______________________

1. Are you currently qualified as a Terrain Board instructor? Yes _____ No _______

2. Physical Terrain Board experience (hrs as an instructor):

   - o 0
   - o 1-100
   - o 101-200
   - o > 200

3. Virtual Terrain Board experience (hrs as an instructor):

   - o 0 hrs
   - o 1 to 3 hrs
   - o 4 to 8 hrs
   - o More than 8 hrs

4. Please rate the ease of use of the overall VTB system (from an instructor's point of view):

   1- Very Difficult - much improvement required
   2- Somewhat Difficult – certain features need improvement
   3- Satisfactory – ease of use is acceptable but could be improved
   4- Somewhat Easy – Minor improvements would help but not required
   5- Very Easy – No improvements required

5. How would you improve the usability of the VTB with respect to?:

   a. Video controller

   b. Menu navigation

c. Classroom environment

d. Teaching modules provided

6. Please use the rating scale below to rate the effectiveness of the VTB in accomplishing the **terrain board learning objectives**:

1- Very ineffective – unable to accomplish any learning objectives
2- Ineffective- unable to accomplish most learning objectives
3- Adequate – able to accomplish some learning objectives
4- Effective – able to accomplish most learning objectives
5- Very effective – able to accomplish all learning objectives
NA- Not Applicable – this objective is not part of our training curriculum
UN- Unsure- have not had enough experience with this parameter

a. Demonstrate both high contrast and low contrast terrain ____
b. Demonstrate effects of illumination level on contrast/detail over different terrains ___
c. Demonstrate the appearance of cultural features (i.e., roads, bridges) ___
d. Cultural lighting (i.e., halo effects, reflections) ____
e. Demonstrate the effects of environmental factors (i.e., weather, dust, smoke) ____
f. Demonstrate differences in albedo for different objects ___
g. Demonstrate the appearance of power lines ____
h. Demonstrate the effect of no illumination ___
i. Demonstrate effects of different color/wavelengths of light on the NVG image ___
j. Demonstrate effects of different color/wavelengths of light under different illumination levels on the NVG image ___
k. Demonstrate effects of different illumination levels on halos ___
l. Demonstrate effects of shadows on the NVG image ___
m. Demonstrate effects of moon elevation and angle on the NVG image ___

7. Please rate the extent to which the VTB allows you to accomplish the overall learning objectives as compared to the physical terrain board. ______

8. Please explain the limitations of those learning objectives you marked ineffective or very ineffective.

9. Please list any other NVG training objectives (not listed above) that could be effectively trained using the VTB.

10. Please list any learning objectives that were not possible to accomplish on the physical terrain board that can be demonstrated on the VTB.

11. Please list any learning objectives that were not possible to accomplish on the VTB that can be demonstrated on the physical terrain board.

12. Regarding the physical terrain board and VTB: (circle all that apply)

A. The virtual terrain board is effective as a stand alone training device
B. The virtual terrain board is not effective as a training device
C. The physical terrain board is effective as a stand alone training device
D. The physical terrain board is not effective as a training device
E. The virtual and physical terrain boards together provide the most effective training

13. What improvements would you recommend for the VTB?

Additional Comments:

12. Appendix B: Terrain Board Learning Objectives Checklist

Terrain Board Learning Objectives Checklist

Name: ____________________ Unit: ______________________

Please use the checklist below to indicate whether the Virtual Terrain Board allows you to accomplish each specific learning objective. If necessary, please use the comment section to elaborate on a specific objective. Select "YES" if you are able to accomplish the learning objective on the VTB. Select "NO", if you are unable to accomplish the objective.

Learning Objectives	YES	NO
1. Demonstrate differences in albedo for different objects		
2. Demonstrate the appearance of power lines		
3. Demonstrate effects of low illumination on contrast/detail over different terrains		
4. Demonstrate the effect of no illumination		
5. Demonstrate effects of different color/wavelengths of light on the NVG image		
6. Demonstrate effects of different color/wavelengths of light under different illumination levels on the NVG image		
7. Demonstrate effects of different illumination levels on halos		
8. Demonstrate effects of moon elevation and angle on the NVG image		
9. Demonstrate differences of albedos in high and low contrast areas		
10. Demonstrate effects of shadows on the NVG image		
11. Demonstrate the effects of various illumination levels on image quality		

Comments:

Objective # ____: ____
____

Objective # ____: ____
____

Objective # ____: ____
____

Objective # ____: ____
____

Objective # ____: ____

13. Appendix C: VTB Students Survey

Virtual Terrain Board Survey
Students

Name: _________________ Date: _______________
Rank: ____________________ Course Attended:_______________
Service: ____________________ Aircraft:____________________

Total Flight Hours: _____ Total NVG Flight Hours: _____ Unit: ______________________
NVG Related Flight Qualifications (e.g., NSI, etc.): ______________________________________
Past NITE Lab NVG Training Courses completed: _______________________________________

1. Please use the rating scale below to rate how effective the VTB was in familiarizing you with the learning objectives listed:

1- Very ineffective – unable to accomplish any learning objectives
2- Ineffective- unable to accomplish most learning objectives
3- Adequate – able to accomplish some learning objectives
4- Effective – able to accomplish most learning objectives
5- Very effective – able to accomplish all learning objectives
NA- Not Applicable – this objective is not part of our training curriculum
UN- Unsure- have not had enough experience with this parameter

a. Demonstrate both high contrast and low contrast terrain ____
b. Demonstrate effects of illumination level on contrast/detail over different terrains ___
c. Demonstrate the appearance of cultural features (i.e., roads, bridges) ___
d. Cultural lighting (i.e., halo effects, reflections) ____
e. Demonstrate the effects of environmental factors (i.e., weather, dust, smoke) ____
f. Demonstrate differences in albedo for different objects ___
g. Demonstrate the appearance of power lines ____
h. Demonstrate the effect of no illumination ___
i. Demonstrate effects of different color/wavelengths of light on the NVG image ___
j. Demonstrate effects of different color/wavelengths of light under different illumination levels on the NVG image ___
k. Demonstrate effects of different illumination levels on halos ___
l. Demonstrate effects of shadows on the NVG image ___
m. Demonstrate effects of moon elevation and angle on the NVG image ___

2. Please rate the extent to which the VTB allows you to accomplish the <u>overall</u> learning objectives as compared to the physical terrain board. ______

3. Please explain the limitations of those you marked ineffective or very ineffective.

4. Please list any other NVG training objectives (not listed above) that could be effectively trained using the VTB.

5. What improvements would you recommend for VTB?

6. Regarding the physical terrain board and VTB: (check all that apply)

F. The virtual terrain board is effective as a stand alone training device
G. The virtual terrain board is not effective as a training device
H. The physical terrain board is effective as a stand alone training device
I. The physical terrain board is not effective as a training device
J. The virtual and physical terrain boards together provide the most effective training
K. I have only been exposed to the VTB.

7. Please list any learning objectives that were not possible to accomplish on the physical terrain board that can be demonstrated on the VTB.

8. Please list any learning objectives that were not possible to accomplish on the VTB that can be demonstrated on the physical terrain board.

For refresher students only:

1- Very ineffective – unable to accomplish any learning objectives
2- Ineffective- unable to accomplish most learning objectives
3- Adequate – able to accomplish some learning objectives
4- Effective – able to accomplish most learning objectives
5- Very effective – able to accomplish all learning objectives
NA- Not Applicable – this objective is not part of our training curriculum
UN- Unsure- have not had enough experience with this parameter

9. Please use the above scale to rate the effectiveness of the VTB in familiarizing students with assigned flying missions. _____

10. What specific VTB training points are most beneficial in familiarizing students with actual flight operations?